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ATOMIC AND ELECTRONIC STRUCTURE OF DEFECTS IN
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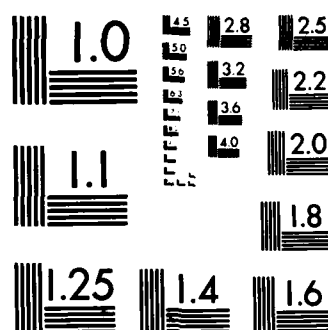
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Final report of A.R.O. Contract No. DAAG-29-80-C-0080

P.I. J.C.H. Spence
Department of Physics
Arizona State University
Tempe, AZ 85287

Period Covered 4/1/80 - 6/30/83

1. Problem studied

This research is aimed at developing new techniques for the characterisation of sub-micron defects in semiconductors by electron beam methods.

2. Summary of main results

2.1 In collaboration with the Berkeley Physics Department, calculations for the electronic band structure of dislocations in silicon have been published (8). These line defects degrade the performance of many real semiconductor devices.

2.2 The degree of atomic roughness at interfaces between $\text{Ga}_x\text{Al}_{1-x}\text{As}$ multilayer films has been determined by atomic resolution transmission electron microscopy (1).

2.3 The "EXELFS" (Extended Electron Energy Loss Fine Structure) technique has been developed and a new technique, in which the local environment of a particular atomic species is probed in a particular crystallographic direction (5). This technique provides similar capabilities to the synchrotron EXAFS method (with similar count rates), but can be applied to submicron regions and recorded in conjunction with an atomic resolution image.

2.4 High resolution images of semiconductor surfaces have been recorded for the first time by reflection electron imaging at 100kV (10). This new technique provides information unobtainable by any other method.

2.5 Incommensurate lattice modulations have been observed by direct atomic resolution imaging in Strontium Niobate. The phase of the modulation

with respect to the host has been determined - this is not possible by any other method (4).

2.6 Microanalysis by electron energy loss spectroscopy has been applied to crystals using an electron probe which is smaller than a single unit cell. A variation of composition was detected within one unit cell (6).

2.7 A Cathodoluminescence system has been built for a transmission electron microscope. This device obtains the optical emission spectrum from isolated defects in semiconductors in correlation with a high resolution transmission electron image. Defects have now been analysed in GaP, GaAs, MgO and diamond (12). Spectra and scanning monochromatic CL images are obtainable at -170°C with submicron spatial resolution.

2.8 A full analysis of the electronic structure of dislocations in diamond is in progress, and will be continued on ARO contract No. DAAG29-83-K-0087. This study involves both visible CL and, high resolution imaging and optical polarization studies.

2.9 A Fourier Transform Infrared Spectrometer has been designed for CL studies in TEM (10). This work will be continued on the new grant, and allow CL studies on silicon and III-V's to be performed at submicron spatial resolution.

3. List of publications

See attached list.

4. Scientific Personnel

P.I.	J.C.H. Spence	Assoc. Prof.
	Dr. J. Lynch	Post Doc.
	Dr. N. Yamamoto	Post Doc.
	M. Disko	Ph D. Student (Physics)



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5. Degrees

During the course of this contract, M. Disko was awarded a Master's Degree in Physics. He will complete a Ph D. in Physics in Sept. 1984 under the new contract.

A.R.O. Journal Articles of J.C.H. Spence funded by A.R.O.
Contract DAAG29-80-C-0080

(May 1980 - May 1983)

1. "The Use of Characteristic Loss Energy Selected Electron Diffraction Patterns for Site Symmetry Determination" Optik, (1980) Vo. 57, p. 451-456.
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4. "High Resolution Electron Microscopy of the Incommensurate Structure in SR2NB207, N. Yamamoto, Acta Cryst (1982) A38, p. 780.
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6. "STEM Microanalysis by Transmission Electron Energy Loss Spectroscopy in Crystals" J.C.H. Spence and J. Lynch, Ultramicroscopy, 91982) Vol. 9. p. 267-276.
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8. "Electronic Structure of the Unreconstructed 30 Partial Dislocation in Silicon" J.E. Northrop, M.L. Cohen, J.R. Chelikowsky, J.C.H. Spence and A. Olsen, Phys Rev. B24, #8, pp. 4623-4628 (1980).
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10. "Surface Imaging of III-IV Semiconductors by REM and Inner Potential Measurements", N. Yamamoto and J.C.H. Spence, Thin Solid Films (1983) Vol. 104, p. 43-55.
11. "Electron Microscopy and Diffraction of Phases in the Al2O3-BAAL2O4 System" N. Yamamoto and M. O'Keefe, J. Appl. Cryst. (1983) In press.
12. "Cathodoluminescence and Polarization Studies of Dislocations in Diamond" N. Yamamoto and J.C.H. Spence. Phil. Mag. (1983).

A.R.O Conference Publications of J.C.H. Spence funded by
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(May 1980 to May 1983)

1. "High Resolution TEM of Semiconductor Defects" J.C.H. Spence, Proc. EMSA, 1980. p. 282.
2. "An EXELFS System and Preliminary Orientation Dependence Results" M. Disko, O. Krivanek and J.C.H. Spence, Proc. EMSA, 1981. G.W. Bailey, Ed, Claitors Publishing Division, Baton Rouge, LA, p. 192.
3. "High Resolution Electron Microscopy of Semiconductor Defects" J.C.H. Spence, Proc EMSA 1981. p. 120.
4. "The Crystallographic Information in Electron Energy Loss Spectra" J.C.H. Spence, O. Krivanek, J. Taftø and M. Disko, Inst. Phys. Conf. Ser. No. 61, Chapter 6, p. 253.
5. "Vacancy Ordering in Vanadium Carbide" N. Yamamoto and Y. Kumashiro, Proc Fortieth Annual EMSA Meeting (Washington) p. 726, 1982.
6. "A Digital on-line Diffractometer and Image Processor for HREM" J.C.H. Spence, M. Disko, A. Higgs, J. Wheatley and H. Hashimoto, Proc. Tenth Int. Congr. on Electr. Micros., Hamburg, (1982) p. 519-520.
7. "TEM/STEM on Line Image Processing Techniques", M.M. Disko, A. Higgs, B. Monosmith, T.M.S. Annual Meeting, March, 1983.
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